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Growth Effects from Trade and Technology

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Growth Effects from Trade and Technology *

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Abstract:

This paper extends the theoretical framework of endogenous growth models in order to investigate how factor re-allocations occurring after the opening of trade can explain sustained growth rates in countries with small endowments of human capital which trade with countries with a greater endowment of human capital.

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Introduction

The question of how trade influences internal growth in countries has long been a matter of interest in economic literature. According to neoclassical models, trade has no direct effect on growth rates themselves, since these are fully determined by investment and savings rates and exogenous technological change in the short run and by exogenous technological change alone in the long run. Trade then is thought only to have indirect effects such as promoting competitiveness and reducing internal distortions. Effects of this kind, however, are insufficient to explain some experiences of export-led growth, for example in East Asian countries.

Recent models in endogenous growth theory (Romer 1986; Romer and Rivera-Batiz 1990; Grossman and Helpman 1989, 1990, 1991; Feenstra 1990) have shown how the development of new technology can lead to long run sustained growth. However, these models fail to explain export-led growth in developing countries, since they predict that only the country relatively better endowed in human capital will enjoy long run output growth. This is due to the fact that the technological sector, i.e. the growth driving sector, increases its share in total production in the human capital rich country after trade is opened: because of this comparative advantage, the countries not rich in human capital will specialize in the production of their traditional goods which are intensive in labour, or natural resources and will cease production of the technological good. In traditional sectors there are assumed to be no (or low) productivity increasing effects, therefore the rate of growth of total production will be lower.

This paper attempts to extend the theoretical framework of endogenous growth models to explain how factor re-allocations occurring after the opening of trade can explain sustained growth rates in countries with small endowments of human capital which trades with countries with a greater endowment of human capital.

The paper is organized as follows: section I describes the model for a closed economy; section II discusses the implications when trade occurs between the small economy and the rest of the world; section III briefly draws some conclusions.

Section I

Endogenous growth in a three sector economy: Structure of the model.

Let us assume there exists a closed economy endowed with three production factors, human capital (H), unskilled labour (L) and a natural resource (T). Production takes place in three different sectors. A high tech sector which uses R&D labs and highly trained technicians to assemble a high tech good. These kind of goods may be aircraft or pharmaceuticals, numerically controlled production systems etc. We shall denote the product of this sector by Y. Production in the second sector is not so technology intensive, still it uses some of the knowledge developed in the high tech sector to produce a different good, which will have a lower level of embodied technology. The production process of this sector will then use technology and an available abundant resource, which for the moment is assumed to be labour. These goods may be televisions, phones, fax machines, VCRs, and light electronics goods, which are assembled by unskilled labour and embody some technology. They may also be various forms of processed foods, elaborated with some degree of technology in production and with a natural resource. This good will be denoted by W. The third sector is the traditional sector which uses standard technology. Examples of this type of production are harvesting or extracting a natural resource or fishing, activities for which variations in the production function are small over time and can be considered fixed; this good will be denoted by Z. Goods Y and W are assumed to be goods in continuous evolution and changing with time, as the result of the application of newly developed technologies, whereas good Z tends to be always the same.

Consumers will maximize an intertemporal, non decreasing, strictly quasi concave, homogeneous of degree one in its arguments, utility function, such that the marginal rate of substitution between goods will be equal to the relative price:

$$U_t=\int_0^{\infty} e^{-\rho(\tau-t)}\log[C_Y(\tau)^{1/3}C_W(\tau)^{1/3}C_Z^{1/3}(\tau)]d\tau \tag{1}$$

with C_Y, C_W, C_Z consumption of goods Y, W, Z; ρ the subjective discount rate; r the real return on riskless assets. Intertemporal optimization process requires that:

$$\frac{\dot{E}}{E}=r-\rho \tag{2}$$

where E:

$$E=(C_Y C_W C_Z)^{1/3}$$

is an index of spending and:

$$r=i-(\frac{\dot{P}_Y}{P_Y}+\frac{\dot{P}_W}{P_Y}+\frac{\dot{P}_Z}{P_Z})/3$$

where i is the nominal interest rate, and P_j is the price of good j, j=y,w,z.

The traditional good Z is produced according to a standard constant returns to scale, Cobb-Douglas technology function that uses labour relatively intensively according to:

$$Z=L_Z^{1-\mu}T_Z^{\mu} \tag{3}$$

with Lz, low skilled labour used in the production of Z and Tz is the natural resource.

Analytically good Y has the same microeconomic structure as appears in Grossman and Helpman (1991); production requires a given amount of human capital and a set of intermediate inputs, according to a Cobb Douglas production function:

$$Y^A = H_{Y^A}^{1-\lambda} D_{Y^A}^{\lambda} \tag{4}$$

with H_y human capital in the production of Y and Dy the set of intermediate inputs entering the production function which is defined as follows:

$$D_Y = [\int_0^N x_i^{\gamma} di]^{1/\gamma} \tag{5}$$

For i $\in$ [1,N] and N being the number of existing varieties at time t.

The definition of D implies that total factor productivity increases with the number of available varieties of intermediate inputs. This can most easily be seen in a symmetric equilibrium where all inputs will bear the same price and are employed in equal quantities in production, so that xi=x and:

$$D = n^{1/\gamma} x$$

The resource embodied in the final good will be:

$$\chi = nx$$

Final output per unit of intermediate input will be:

$$D/\chi = n^{(1-\gamma)/\gamma}; 0<\gamma<1$$

which implies productivity increases with the number of varieties available.

As Ethier explains, this property comes from increased specialization in production: manufacturing is considered as an increasing number of finer and finer production processes. One could think for example of a producer service (Ethier 1982). Another possible way of describing the process is to take into consideration the new machines introduced into the production process that become more and more highly specialized in executing a particular step in the production process. For example the robots in the car production, every one of which performs a particular task on every item; in this way x would represent a specific job or operation that becomes mechanized in production.

Intermediate inputs entering the production of good Y are developed by entrepreneurs who set up R&D laboratories. Each new variety developed is be covered by patent and the entrepreneur will be producing the good as a monopolist. Price of the intermediate good will then be fixed as a mark-up over production cost:

$$P_x = \frac{1}{\alpha} \delta_{Hx} w_H \tag{6}$$

where δ_{Hx} is the input output coefficient for human capital employed in the production of innovative intermediate goods. We assume that in the development of new varieties, human capital employed in the R&D labs is the primary input. In principle it would be possible to include other inputs but this has not been done here for the sake of simplicity.

The number of available varieties N will then depend on the amount of human capital dedicated to R&D activities in sector Y, and on the given state of knowledge. In this case knowledge is thought to be embodied in each variety, so that the number of existing varieties positively influences the rate of new inventions:

$$\frac{\dot{N}}{N}=\frac{H_x}{a_{Hx}} \tag{7}$$

where a_{Hx} is the human capital input coefficient, i.e. the amount of human capital necessary to develop a new variety. This coefficient could be assumed to vary with time, as the country acquires experience in the R&D activity.

By market free entry conditions in the intermediate input sector, the present value of future discounted profits must be equal to the cost of entry:

$$\int_0^{\infty} e^{(R_t-R_\tau)}\pi_n(\tau)d\tau=\frac{1}{N}(w_H a_{Hx})=v_n \tag{8}$$

where N and a_{Hx} might be thought to depend on the country's experience in the innovative sector. Finally there must be a market no-arbitrage condition, which requires capital gains and relative profits to be equal to the return on riskless assets:

$$\frac{\pi_n}{v_n}+\frac{\dot{v}_n}{v_n}=r \tag{9}$$

Given the symmetry assumption whereby in equilibrium every innovative variety will enter the production function in the same amount and will bear the same price, the profits of the innovating manufacturer will then be expressed by:

$$\pi_n = \frac{1}{N}(p_x x - w_H H_x) = \frac{1}{N}\{p_x[\frac{H_x}{\delta_{Hx}}] - w_H H_x\} = \frac{1}{N} w_H H_x (\frac{1-\alpha}{\alpha}) \qquad (10)$$

where H_x is the amount of human capital used in the production of the innovative varieties.

Differentiating (8) over time gives rise to an equilibrium condition for v and N, in the hypothesis that a and w are fixed, r is constant and there is a constant growth rate of N. Alternatively one could assume that in labour market equilibrium, decreasing input coefficients which represent increased human capital productivity in research are perfectly balanced by increases in wages to human capital:

$$-\frac{\dot{N}}{N} = \frac{\dot{v}_n}{v_n} \qquad (11)$$

The combination of equations (9) (10) and (11) gives rise as in Grossman and Helpmann (1991) to a positive constant long run rate of increase in N given by the equilibrium of the dynamic system, which in turn implies constant increase in productivity at any given factor supplied to sector Y.

For the sake of simplicity this will be referred to as:

$$\frac{\dot{N}}{N} = \omega; \quad \frac{\dot{N}}{N} = \frac{\pi}{v} - \rho \qquad (12)$$

where ρ is the long term discount rate.

Good W is also produced with a standard Cobb-Douglas technology function and from a set of intermediate inputs D':

$$W = L_W^{1-\lambda} D_W^{\lambda} \tag{13}$$

D_W, set of intermediate inputs entering the function is defined as follows:

$$D_W = [\int_0^M x_j'^{\gamma} dj]^{1/\gamma} \tag{14}$$

Where M is the total amount of varieties entering production and j ∈ [1,M].

The varieties x' entering the production function of W are the result of an activity of assimilation of the technology embodied in each variety x; in short they are imperfect imitations. They can be thought as clones or cheaply made machinery, which can be good substitutes for the original technology but not perfect substitutes, because, for example, of the technical assistance supplied or other technological features. They can also be thought of as particular adaptations of existing technology, such as refrigerating systems for tropical climates etc.

The set of elements x',is defined such that each and every element is an image of x, but the converse is not true:

$$f{:}x \to x';$$
$$f(X) = X';$$
$$x_1 \neq x_2 \Rightarrow f(x_1) \neq f(x_2)$$

This implies that for every original developed technology there can be more than one clone, but each clone corresponds to only one particular technological good.

Entrepreneurs assimilate existing technology with the help of R&D labs which essentially modify or copy existing designs. Since the amount of human capital necessary to assimilate a given technology is lower than the amount used to develop the original variety, the production cost for the assimilated variety will be lower. So, given that x'j is a differentiated variety and will have a monopolisitic pricing structure, it will then have a lower price than the original:

$$p_{x'} = \frac{1}{\beta}(\delta_{Hx'} w_H) \tag{15}$$

and again $\delta_{Hx'}$ represents the input output coefficient for human capital employed in the imitative sector, and β the monopolistic markup.

Given the assumption on the production function in (4) and (13) for Y and W, there is no direct competition between producers of varieties x and x' because they will sell to different producers. The question then relies on the assumption for the production function which it essentially incorporates and on the assumption about the different nature of the technological goods being produced. On the one hand, very high tech good, such as precision instruments, require perfect intermediate inputs and skilled labour for their production; on the other hand, light electronic or electrical equipment can be assembled with the employment of low skilled labour and with intermediate inputs that are not quite the same as those used in the production of very high tech goods or do not necessary need to be of top quality. In the described model the crucial assumption is that intermediate inputs fully specify the nature of the final good being produced.

In principle this assumption can be relaxed to allow for producers of original and imitated varieties to compete in supplying the producers of technological goods. In this case there would be a dual pricing structure in the intermediate inputs market. The producers of original varieties that have not yet been assimilated, behave as absolute monopolists, whereas producers of assimilated varieties will be acting in an oligopolistic market. The structure of the model will remain basically the same except for further complications to the structure introduced by multiple pricing. Future discounted profits would have to take into account the risk of being imitated, and the capital no arbitrage condition. The profit function would have to be modified to allow for the hazard of being assimilated, and the capital no arbitrage condition will require higher capital gains and higher profits in equation (8) for an entrepreneur to enter the market; but for the sake of simplicity this issue will not be developed here.

Dynamics of the assimilation of technology

We assume that after a certain time, the technology embodied in the innovations that have been developed in the high tech sector spreads to the rest of the system. This occurs because entrepreneurs in the low tech sector hire human capital that with some effort reproduces the original design and then introduces a particular variation. For this activity a certain lapse of time is essential in order to observe the original invention and to understand the underlying technology. So, we can assume, that at any moment in time, given the total set of existing innovations N, there is a fraction ξ of these which is impossible for others to imitate. The rate of assimilation of existing varieties will then be assumed to be a function of the technical features of the innovation which influences the degree of observability of the original. The probability that the embodied technology is assimilated will depend on amount of human capital employed in the R&D of the low tech sector, and on the difference between the existing innovations that are potentially imitatable N* and those that have been already imitated. The function will then take the form:

$$\frac{\dot{M}}{M}=\sigma p\left(\frac{N^{*}-M}{M}\right) \qquad (16)$$

Where σ is a function of the technical features of the originals; p is a function $p=p(H_m)$, H_m: human capital employed in the low tech sector with $p(0)=0$ and $p(\infty)=1$; and finally $(N^*-M)/M$ represents the technological gap.

gap.

Equation (16) is of the logistic type, has a short run dynamics of the same kind and converges to the long run value of $\dot{N}/N$

Given the assumption about N*, which is a constant fraction of N, and the equilibrium rate of innovation for the high tech sector g, the long run rate of assimilation will be exactly equal to the rate of innovation of new varieties.

So the cost for a potential entrepreneur to reproduce a given variety will depend on the extent of the technological gap as well as on the cost of human capital, where the human capital input coefficient for the low tech sector is assumed to be much lower than that for the high tech sector. The market entry equilibrium condition for the low tech sector will then be:

$$\int_0^{\infty} e^{(R_t - R_\tau)} \pi_m(\tau) d\tau = \frac{1}{\alpha(N^* - M)}(w_H a_{Hm}) = v_m \qquad \textbf{(17)}$$

and the capital no arbitrage condition will be analogous to that of the high tech sector.

The rate of growth for assimilated varieties of the economy will then be in equilibrium if:

$$-\frac{\dot{M}}{M} = \frac{\dot{v}_m}{v_m} \qquad (18)$$

and since:

$$\frac{\dot{M}}{M} = \frac{\dot{N}^*}{N^*} = \frac{\dot{N}}{N} \qquad (19)$$

there will be a balanced growth rate for the economy.

The growth rate for this economy as referred to above, is given by the productivity growth rate, i.e. the rate of introduction of new varieties in production. In this case there are two activities where the introduction of new varieties is productivity increasing. The total growth rate for the economy will then be:

$$g=\frac{\dot{N}+\dot{M}}{N+M} \tag{20}$$

which holds at every instant in time and at its long run equilibrium value will be equal to the growth rate of innovative varieties.

The growth rate of total output, however, will depend on the relative share of the two technological sectors in the total output.

Section II

Opening the economy to trade

Trade in endogenous growth models is usually thought to have three basic effects: an integration effect, a knowledge spill-over effect and a factor re-allocation effect.

The integration effect in this case applies to the high tech sector that opening to trade will increase the total number of available inputs and therefore there will be a once and for all productivity increase. The increased number of x type varieties should also speed up the rate of assimilation in the short run, since the technology gap has grown greater.

The knowledge spill-over effect in this case can be introduced into the assimilation function. Parameter σ was stated to be a function of the degree of observability of the variety. In fact it is better to define this parameter as representing the frequency at which it is possible to come into contact with the variety. In an open economy this frequency can be thought of as a function of existing trade barriers. In this context, the opening of trade will have a short run effect of increasing the speed of imitation. Neither of these effects will modify long run rates of growth.

The factor re-allocation effect determines in the long run the rate of output growth for the country, and depends on the assumptions on the relative endowments of the country. For this reason separate cases will be analyzed. By equilibrium conditions of a Heckscher-Ohlin square 3x3 model, the economy will have to be ranked uniquely in terms of the endowments of each factor, at the same way in which each activity is ranked uniquely in terms of its intensiveness in each factor from the assumptions on the production functions.

Finally allowing trade in intermediate inputs will not alter the conclusions of trade theory, but special cases will be discussed.

a) Labour abundant country

We assume that the country in question is relatively well endowed in unskilled labor and scarce in human capital as compared to the rest of the world.

When trade is opened, the traditional sector will expand and the high tech sector will surely contract, since these are the sectors of comparative advantage and disadvantage respectfully. In the analogous two sector case discussed in Grossman and Helpman (1991), output growth will tend to contract because the productivity increasing sector reduces its share over total output. However, in this case, human capital crowded out of the high tech sector will have a declining wage, while the economy still enjoys a comparative advantage in labour intensive activities. This stimulates the expansion of the low tech sector, and the economy ends up by exporting the low tech good and importing the high tech good. Hence contraction in the high tech sector will be balanced by an expansion in the low tech sector which also increases productivity. In this case, output growth does not necessarily decline after the opening of trade because expansion of the low tech sector can still lead to sustained output growth.

This effect is achieved because of the joint hypothesis that the country has a basic endowment in human capital and that the sector assimilating technology from abroad is labour intensive. In this respect this conclusion is particularly interesting because it may provide a key with which to analyze the success of East Asian countries in exporting low tech, labour intensive goods.

b) Natural resource abundant country

We assume that the country is relatively well endowed in natural resources.

If analyzed in the same way as the preceding case, the natural resource endowed country will experience the usual Grossman and Helpmann effect for which output growth will contract as an effect of the contraction of technological sectors. There is little incentive for development of a low tech sector if the comparative advantage does not lie in labour intensive goods.

Consider, however, a different model where the production function for the low tech good is:

$$W=T_W^{1-\lambda}D_W^{\lambda} \tag{13a}$$

and D_W defined in the usual way (9). This kind of good might be found for example in the food industry. Food is certainly elaborated with a primary natural resource, but the latest food technology has greatly modified the production process and the varieties available. A similar case can be made for the chemical industry, synthetic rubbers for example. A better way to describe this might be the model of increasing product quality described in Grossman and Helpman (1991), which has the same dynamic structure as the product differentiation model. In this case, entrepreneurs in this sector are assimilating foreign quality improvements, and producing the same kind of growth effect through quality improvements.

Given this production function for the assimilating industry, again, after the opening of trade there will be falling wages to human capital and incentives to develop natural resource intensive activities. Since the sector assimilating foreign technology is intensive in natural resources, the country can still enjoy increasing rates of growth after trade is opened.

Allowing for trade in intermediate inputs in either context does not much affect the conclusions of the model. Monopolists in the assimilating sector will be competing with monopolists in the same sector abroad. In all cases, human capital has a declining wage, while abroad returns to human capital will be increasing. This might imply that monopolists in the small economy will enjoy substantial cost advantages that will enable them to drive foreign competitors out of the market and end up exporting low tech intermediate inputs to the rest of the world. However, the cost of human capital can still remain too high to be competitive in the low tech intermediate inputs. This merely implies that intermediate inputs will have to be purchased from abroad together with the high tech goods.

In either case, whether trade in intermediate inputs is allowed or not, the development of the technology assimilating sector will depend crucially on the price at which the intermediate inputs are available inside the economy with respect to the foreign competitors in the same sector.

Section III
Conclusions

In the models developed by Grossman and Helpmand (1991), the development of a "technological sector" which enjoys increasing returns enables long run sustained growth. Once the economy opens to trade, by comparative advantage laws high tech and R&D will mostly take place in human capital abundant countries. Countries less rich in human capital will still be able to enjoy increasing rates of output growth only if there is some assimilation of foreign developed technology. In the model examined, it was shown how, in a free trade regime, there will be no incentive for a country less rich in human capital to develop the technology assimilating sector, if this sector does not produce a good for which the country has a comparative advantage in terms of factor endowments. Viceversa, free trade stimulates the development of the technology assimilating sector in countries where the technology sector uses an abundant factor. In the context of the model considered, even countries less endowed in human capital can experience output growth after trade is opened.

Another observation concerns the role of human capital in the growth process. The model developed suggests that the country may need a considerable endowment of human capital for the technology assimilating sector to develop, and hence to enjoy a positive rate of growth. In this respect it is possible for the country to influence its future growth rates by investing in human capital. Further, if human capital were to accumulate through time, it would then be possible to think in terms of a shift in the country's comparative advantage from imitated, low technology goods to high technology goods. The interesting question is how such shift towards more high tech might goods occur, which in turn depends on whether human capital accumulates naturally or only through government intervention in education policies.

Some final remarks

According to the previous discussions, a country's growth pattern could be described in terms of shifting comparative advantage towards more technology sophisticated goods. Some countries seem to have experienced exactly this kind of effect. Korea, Hong Kong, Japan, all began by exporting textiles and clothing, which are typical labour intensive goods. After a while they started to export transistors and valves, later moving on to tv sets b/w then color. These are all low tech goods that require labour for assembly. Now Japan is one of the world leaders in high tech R&D and Singapore has also developed its own R&D in specific sectors (for example CD ROM). These are also countries that have enjoyed spectacular growth rates over the last decades.

The question that arises is whether other developing countries could reproduce such a pattern of growth. The crucial point then should be to identify exactly the causes of growth in these countries. In other words, did growth in East Asian countries depend strongly on acquisition of comparative advantage in a sector that was assimilating foreign technology, or did growth only occur because this particular sector was enjoying and increase in demand throughout the whole period. From the World Trade Tables, it can be seen that trade in technological goods is the category that has grown most over the last decades.

If the first alternative were correct, then other less developed countries should also be able to catch up. The crucial question will then concern the choice of an adequate sector in which to compete. In some ways Chile has produced an answer to this question. Chile has undergone a extensive industrial restructuring in the last years and has enjoyed some increase in output growth together with the development of the food sector. Chileans have considerably upgraded the quality of produced food and are now able to compete with industrialized countries in international markets. If this modernization keeps on pace with that of developed countries, this might prove to be a successful strategy for a country that is endowed with natural resources.

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